Ultraviolet Curable Powder Coatings With Robotic Curing for Aerospace Applications

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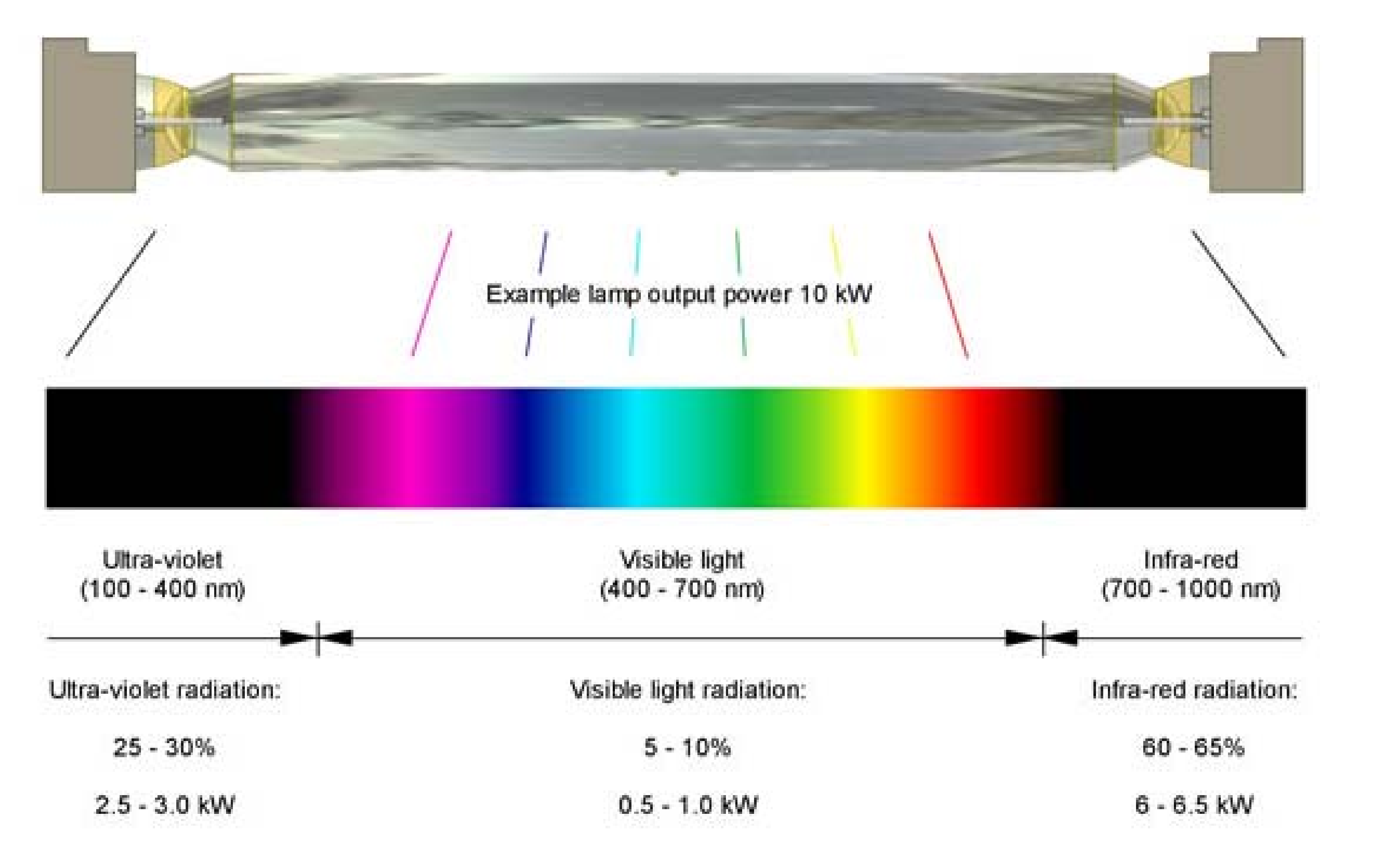
Outline

- UV-Cure Technology
- UV-Curable Powder Coatings Overview
- Robotics as an aid to Curing
- Current Status of ESTCP Project WP-0801

UV Cure Technology

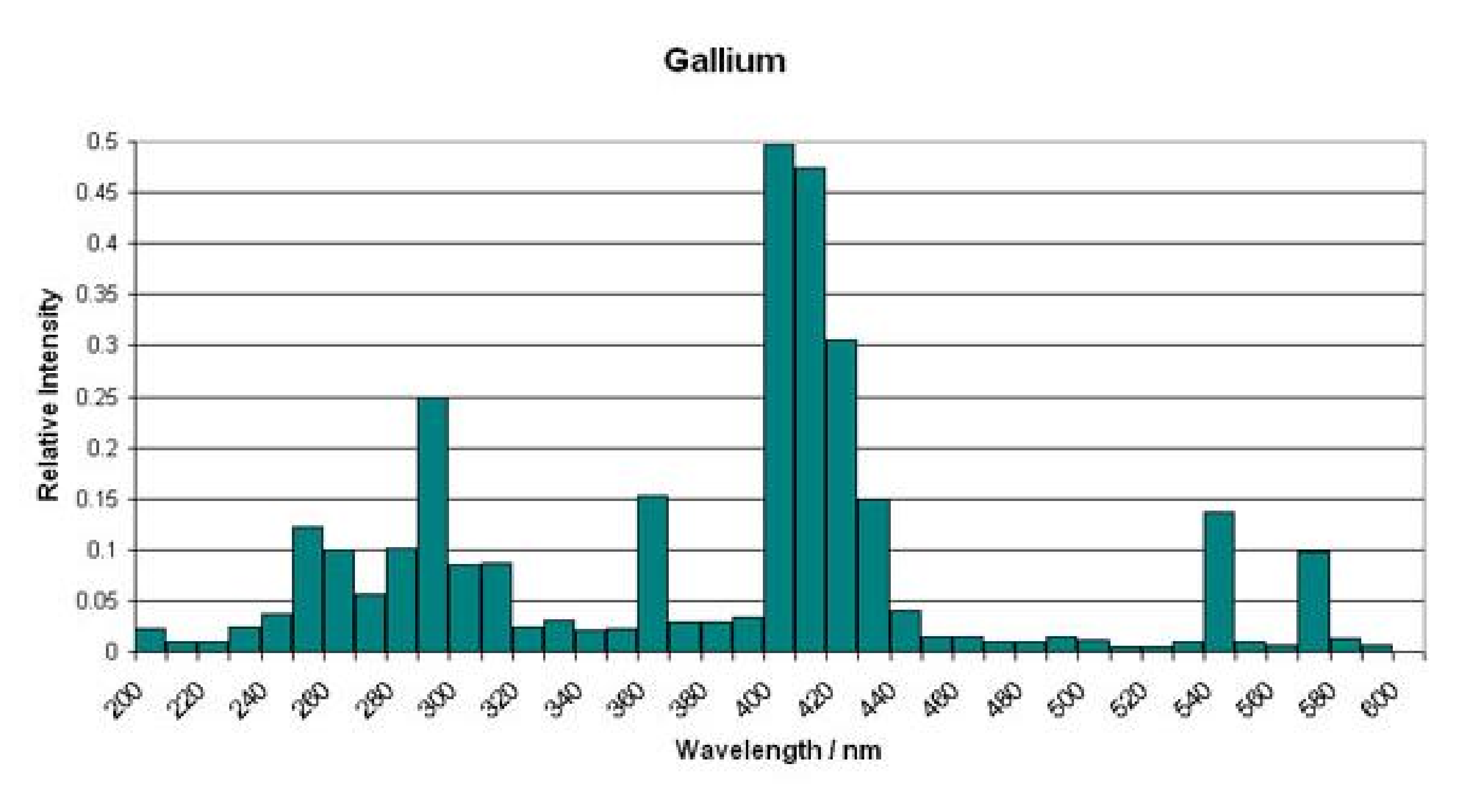
UV Cure Technology



Typical medium pressure mercury discharge lamp power distribution.

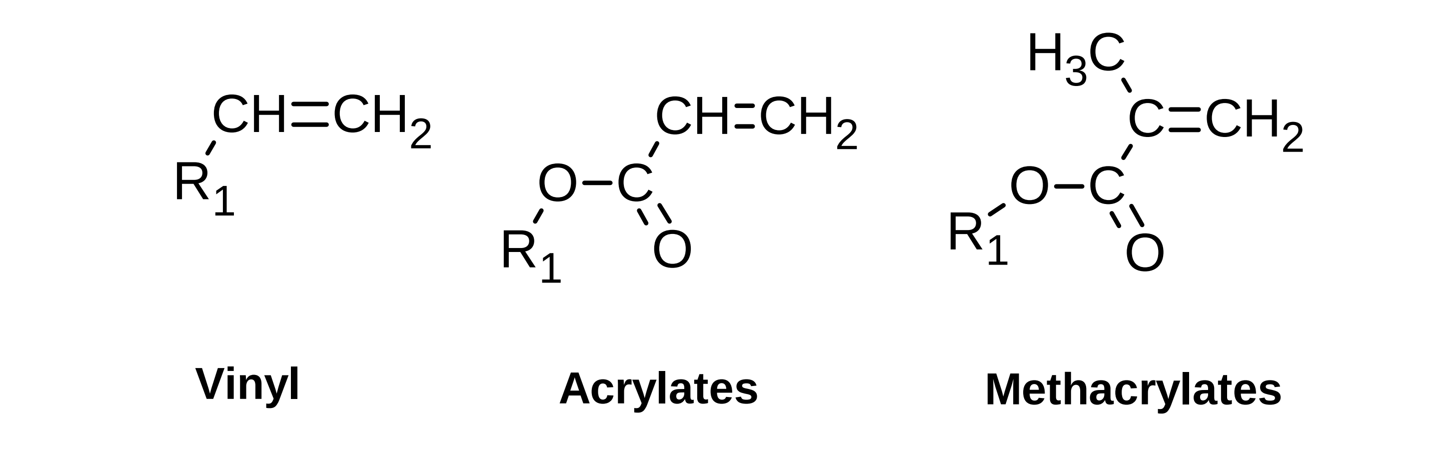
UV-Cure Technology

- Typical Ultraviolet Lamp Spectra:



UV Cure Technology

- Chemistry of UV-cure coatings
  - Can be virtually any polymer matrix used for organic coatings
  - The common denominator is the presence of a UV light reactive species on/in the polymer matrix
  - Commonly vinyl, acrylate or methacrylate groups

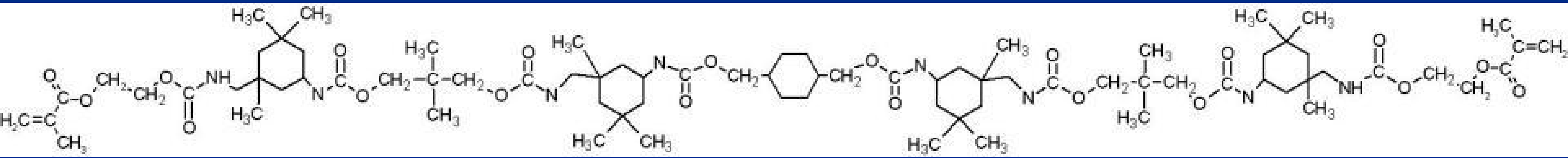


UV Cure Technology

- Chemistry of UV-cure coatings
  - Typically, the most common UV curable powders are:
    - Polyurethanes
    - Polyesters
    - Epoxies
  - For the UVCPC project, we use a mixture of light activated polyurethanes and polyesters

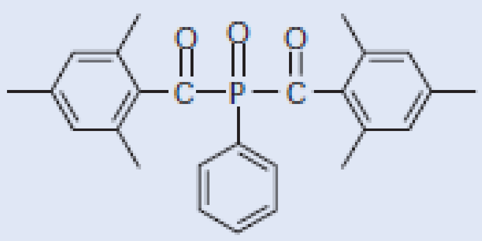
UV Cure Technology

- Polyurethane diacrylate (typical) MW ~2000 - 4000



- UV Cure formulations also require:
  - Additives such as pigments and flow agents
  - Photoinitiators

IRGACURE 819 and IRGACURE 819 DW



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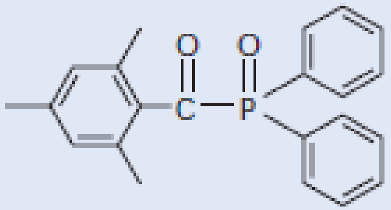
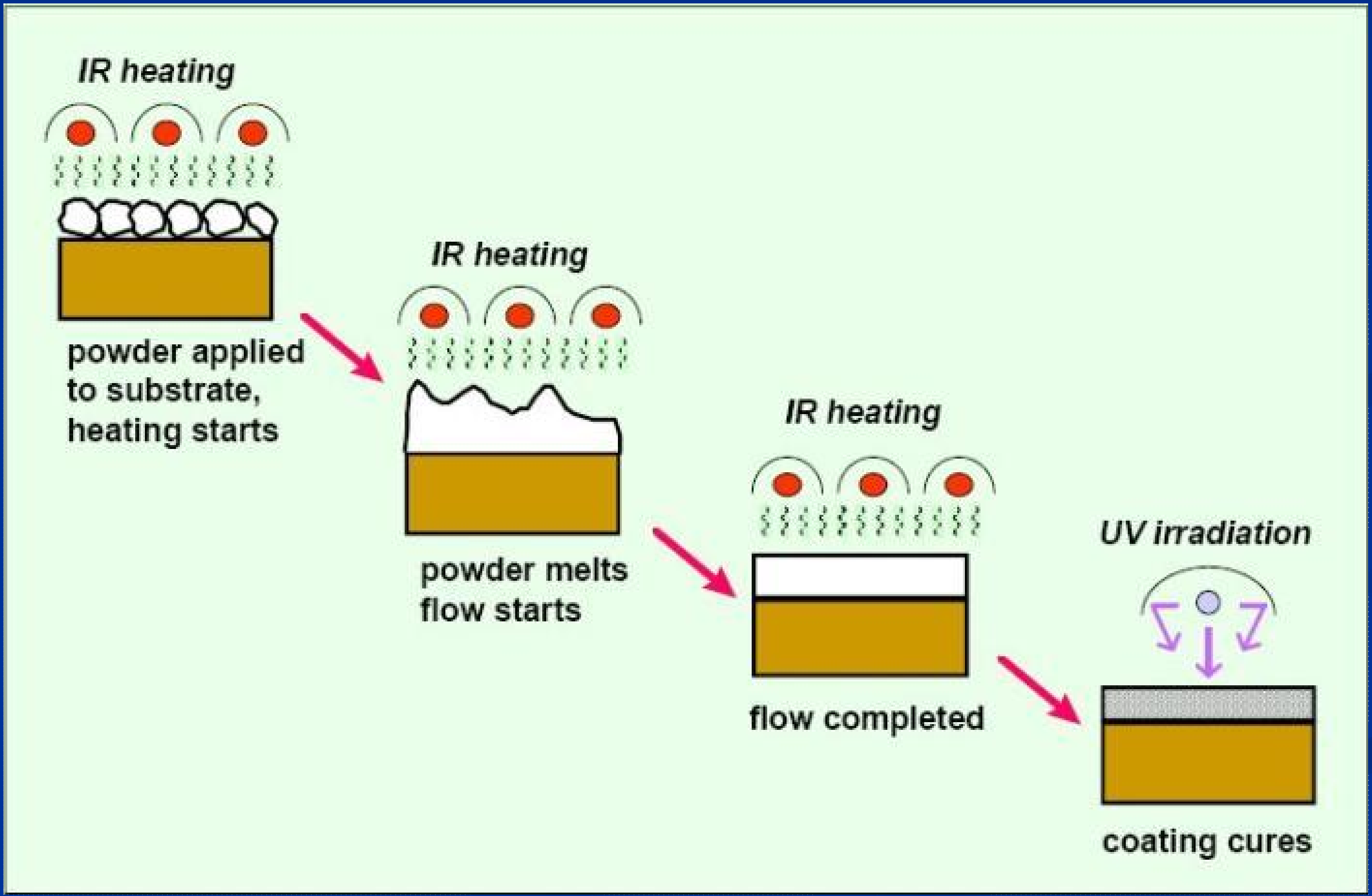


UV Cure Technology

- Powder is applied using electrostatic powder gun
- Applied powder is cured with IR and UV lights mounted on robotic curing system

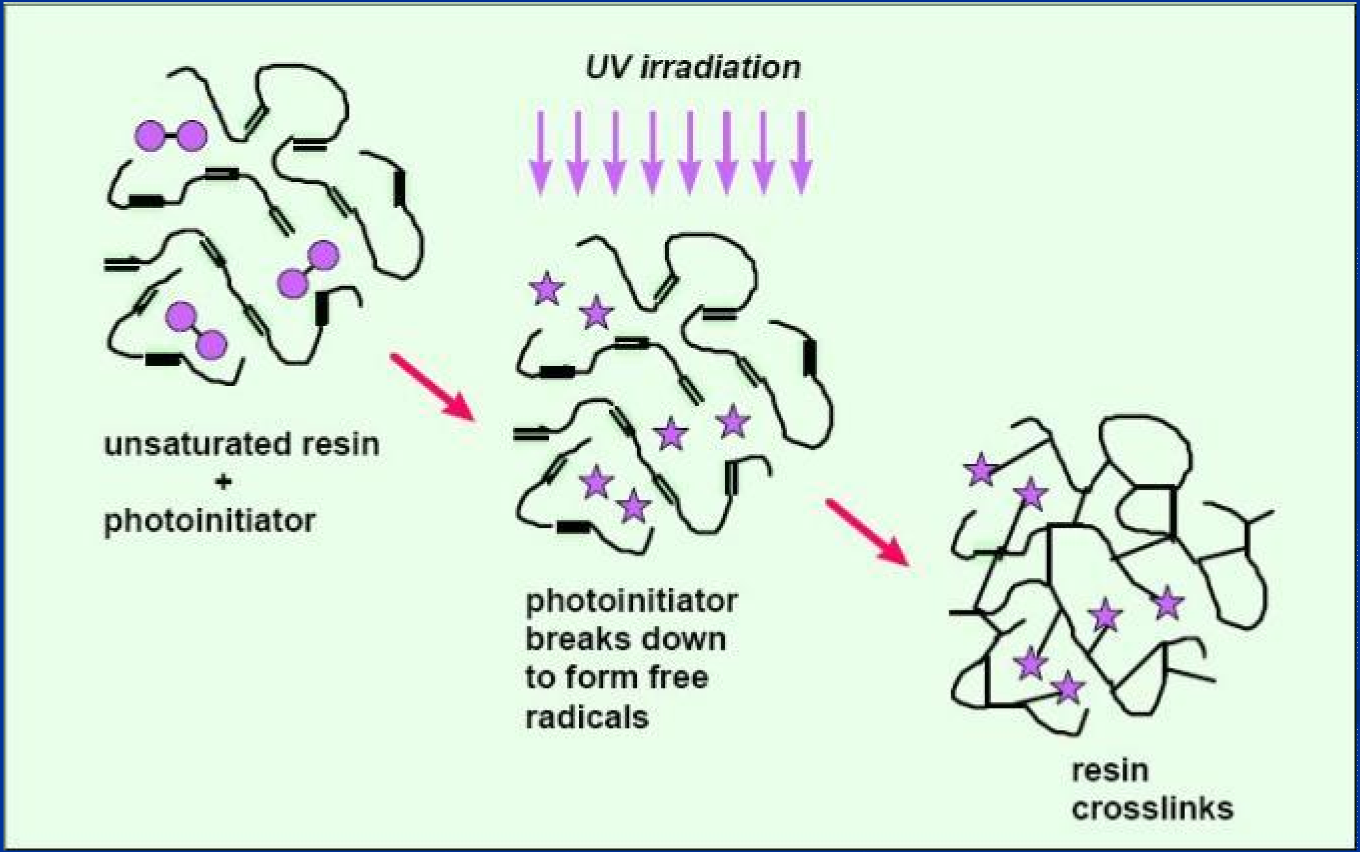
UV-Cure Technology

- The UV cure powder process:



UV-Cure Technology

- Crosslinking occurs during UV irradiation:



UV-Curable Powder Overview

UV-Curable Powder Overview

- Previous ways of thinking about powder
  - Coating cure temperatures – typically above 220°C
  - Prohibitive for use on tempered metals (Al, Mg, Ti)
  - Prohibitive to use on composites
  - Powder coatings were designed as barrier protection

UV-Curable Powder Overview

- Modern powder coatings can be formulated to have:
  - Lower melt & flow temperatures (< 110°C)
  - UV or EB cure functionality can be added
  - Various advanced non-chrome corrosion inhibitors

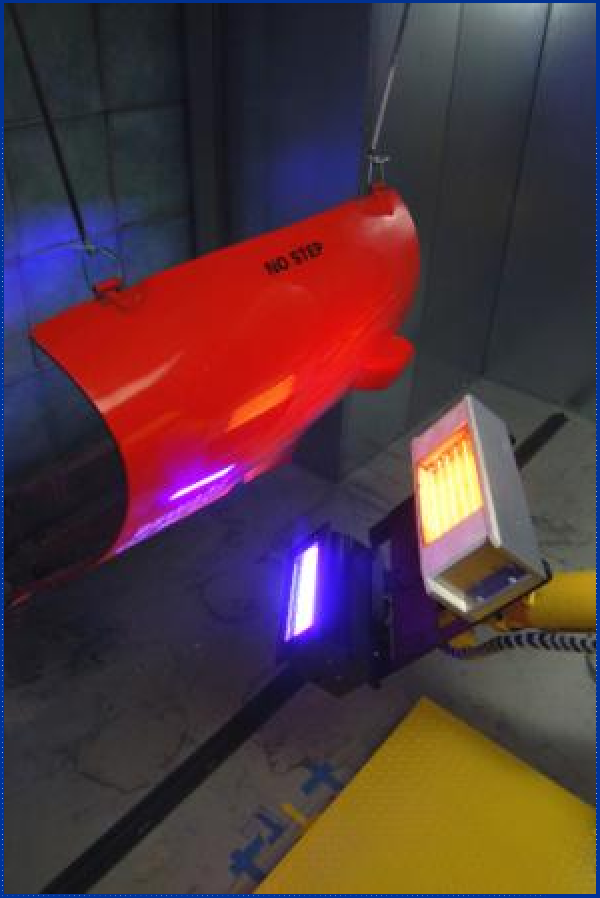
UV-Curable Powder Overview

- Advantages of UV-cure powder coating:
  - Elimination of volatile organics (VOC)
  - Elimination of hazardous air pollutants (HAP)
  - Reduction/elimination of hazardous waste
  - Transfer efficiencies as high as 95% (w/reclaim)
  - Decrease in thermal exposure.
  - Large bulky parts that cannot fit into existing ovens can be coated and cured.
  - UV-cure powder requires less energy because the energy is focused to a specific part only as long as needed.

Robotics as an Aid to Curing

Robotics as an Aid to Curing

- Why Use Robots?



- "Big Bird"

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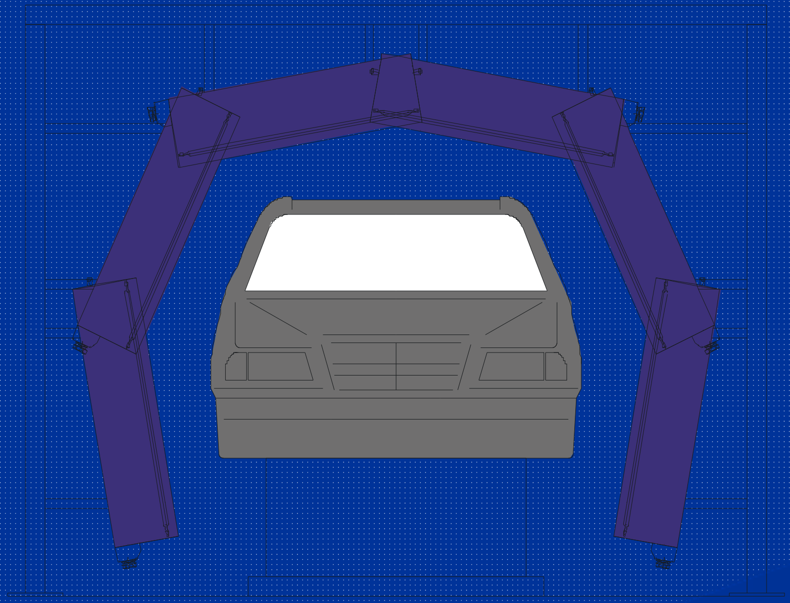
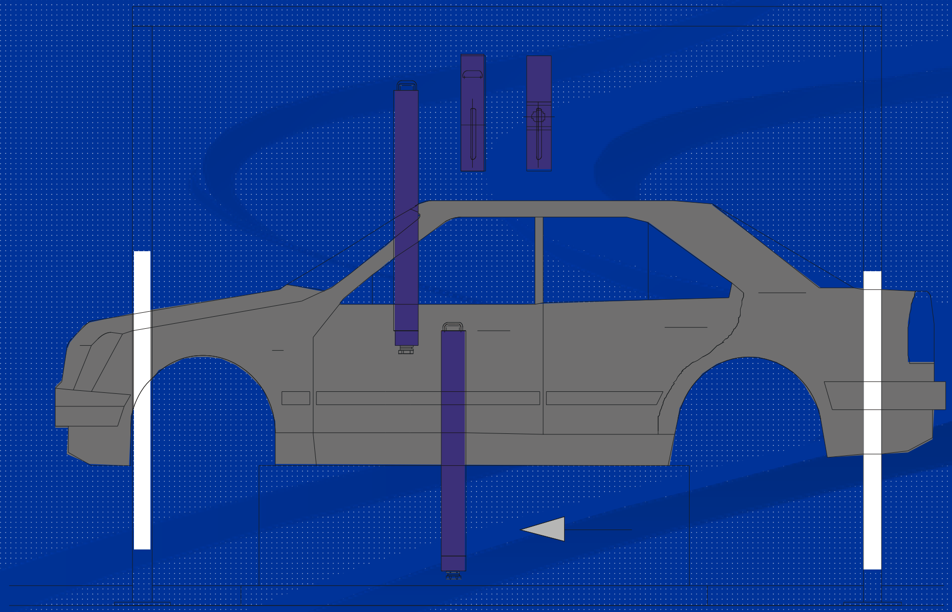
Robotics as an Aid to Curing

- Light tunnel approach using various size UV lamps to optimize cost and exposure





Robotics as an Aid to Curing

- Drawbacks of fixed lamp approach
  - High Capital Costs
    - Lamps, cooling, fixtures, integration
  - High Operating Costs
    - Replacement parts
    - Energy
    - Downtime
  - Technical Adequacy
    - Complete cure
    - Proper Re-alignment
    - Mixed product

Robotics as an Aid to Curing

- Advantages of Robotic Curing
  - Robots ensure repeatability
  - Robots with UV sources can maintain extremely close target distances
  - Robots can be re-programmed in seconds
  - Robotic curing is well suited to large or complex parts
  - Robots eliminate need for many lights

ESTCP Project WP-0801

ESTCP Project WP-0801

- The Problem:
  - DoD spends millions of dollars annually on solvent-based coatings
  - Hexavalent chrome primer use still very widespread
  - Many topcoats contain hazardous diisocyanates
  - Contains or requires volatile solvent use
  - Significant hazardous waste costs
  - Hazardous materials pose risks to human health and environment
  - Process times measured in hours to days

ESTCP Project WP-0801

- The WP-0801 Objectives are:
  - Demonstrate a VOC/HAP-free, diisocyanate free, Ultraviolet cure powder coating (UVCPC) on DoD hardware
  - Demonstrate state-of-the-art robotics for curing

ESTCP Project WP-0801

- Requirements of a UVCPC for military use:
  - Must perform at least as well as MIL-PRF-23377 primer
  - Must also perform as well as MIL-PRF-85285 topcoat
  - Can be prepared in gloss, semi-gloss, and flat finishes

ESTCP Project WP-0801

- The UVCPC is now available in gloss, semi-gloss and a flat finish

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- Robotic Curing System:
  - Robot carries the Infrared and Hg vapor UV lamps

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- Powders:
  - Currently utilizing one vendor
  - Two colors, gloss white, semi-gloss and flat gray
  - Current powder melts and flows at 120°C
  - Will undergo strict validation testing to Mil Standards

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- Planned demonstration weapon systems:

EA-6B wheels, landing gear

HH-65 helicopter

P-3 wheels, landing gear, radomes

Mk-48 ADCAP torpedo

HC-130 main landing gear doors

A-10 wing

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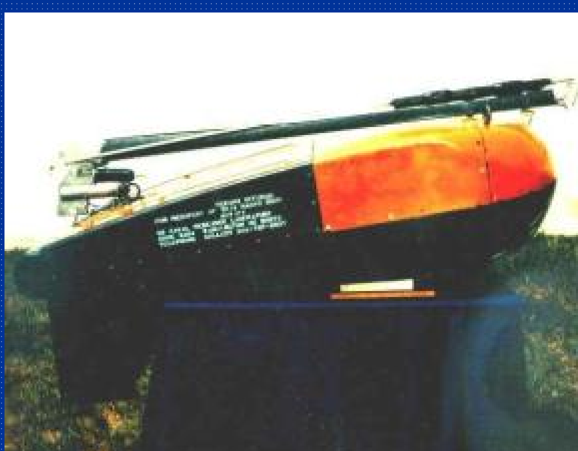
- Planned demonstration weapon systems (cont.):

Submarine icecaps

EA-18G wheels, landing gear

Ammunition and storage cases



Submarine communication buoys

Submarine interior components

ESTCP Project WP-0801

- Testing:
  - Validation testing continues.
  - Panels are now at KSC outdoor exposure facility.

ESTCP Project WP-0801

- Issues:
  - Adhesion problem to 2024 alloy aluminum

ESTCP Project WP-0801

- Issues:
  - Adhesion problem to 2024 alloy aluminum
    - Adhesion failures on both Alodine 1600 and PreKote
    - Determined to be based on amount of Copper in alloy
    - Adhesion excellent on low copper alloys and 4130 steel
    - Focused on deoxidizer step, switched from alcoholic phosphoric acid to Turco® 6/16 deoxidizer/etchant
    - Excellent adhesion results over Alodine 1600 (chromate), Alodine 8800 (sol-gel) and Alodine 5200 (Zr chemistry)
    - Fair to poor results over Alodine 1200S (chromate), and Alodine 5900 (tri-chrome)

ESTCP Project WP-0801

- Issues:
  - Initial test results on 1008 steel less than desirable
    - Failed 500 hour SO_2 corrosion test
    - Showing signs of failure after 1 month beach exposure
  - Awaiting results on 4130 steel for comparison
  - Based on future 4130 results, may require reformulation or primer application for steel components
  - Decision TBD

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- Progress:
  - Completed Building 2801 update
  - Facility is ready to receive robotic curing system

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- Successes:
  - Successfully demonstrated capability to UV powder coat and cure on non-conductive materials.
  - Successfully created flat finish UVCPC
- Studies:
  - Evaluation of alternative UV sources
  - Evaluation of alternative application methods

ESTCP Project WP-0801

- Major Program Milestones:
  - Joint Test Protocol submitted Sept 2008
  - Robot acquired and integration completed
  - Component identification complete
  - Powder and substrates order complete
  - Validation testing continues Apr 2011
  - Draft Demonstration Plan Jan 2011
  - Field Service/Demonstration begins Jul 2011
  - Joint Test Report draft Aug 2011
  - Final Report Mar 2014

Thank You!

Points of contact for UV-curable Powder Coatings ESTCP Project WP-0801:

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Questions?